US009934811B1

(12) **United States Patent**
Sun et al.

(10) **Patent No.: US 9,934,811 B1**
(45) **Date of Patent: Apr. 3, 2018**

(54) **METHODS FOR CONTROLLING STRAY FIELDS OF MAGNETIC FEATURES USING MAGNETO-ELASTIC ANISOTROPY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 807 days.

(21) Appl. No.: **14/312,317**

(22) Filed: **Jun. 23, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/949,390, filed on Mar. 7, 2014.

(51) **Int. Cl.**

G11B 5/858	(2006.01)
C25D 21/04	(2006.01)
G11B 5/84	(2006.01)
C25D 5/18	(2006.01)
C25D 5/00	(2006.01)

(52) **U.S. Cl.**
CPC ***G11B 5/8408*** (2013.01); ***C25D 5/003*** (2013.01); ***C25D 5/18*** (2013.01); ***G11B 5/858*** (2013.01)

(58) **Field of Classification Search**
CPC G11B 5/858; C25D 5/003; C25D 21/04
See application file for complete search history.

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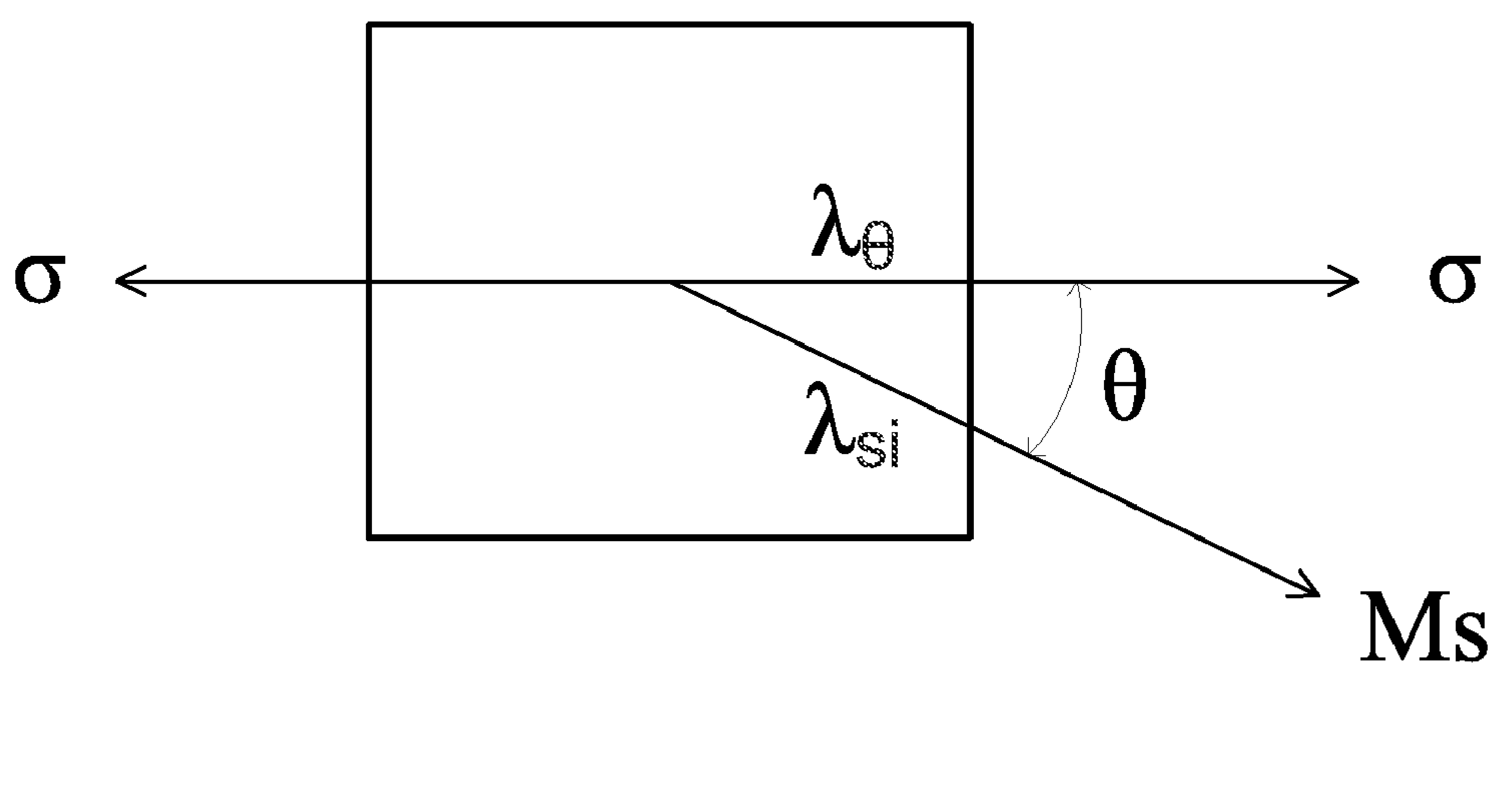
(57) **ABSTRACT**

Systems and methods for controlling stray fields of a magnetic feature are provided. One such method can involve selecting a plurality of materials for a magnetic feature, selecting a plurality of additives, combining the plurality of materials for the magnetic feature and the plurality of additives in an electrolyte solution to form a combined solution, adding nitrogen to the combined solution, degassing the combined solution, depositing the combined solution as a thin film on a wafer using pulse plating, and lapping the thin film to form an edge of the magnetic feature. In several embodiments, the magnetic feature is a component of a magnetic transducer such as a writer pole, a reader shield, or a writer shield.

20 Claims, 5 Drawing Sheets



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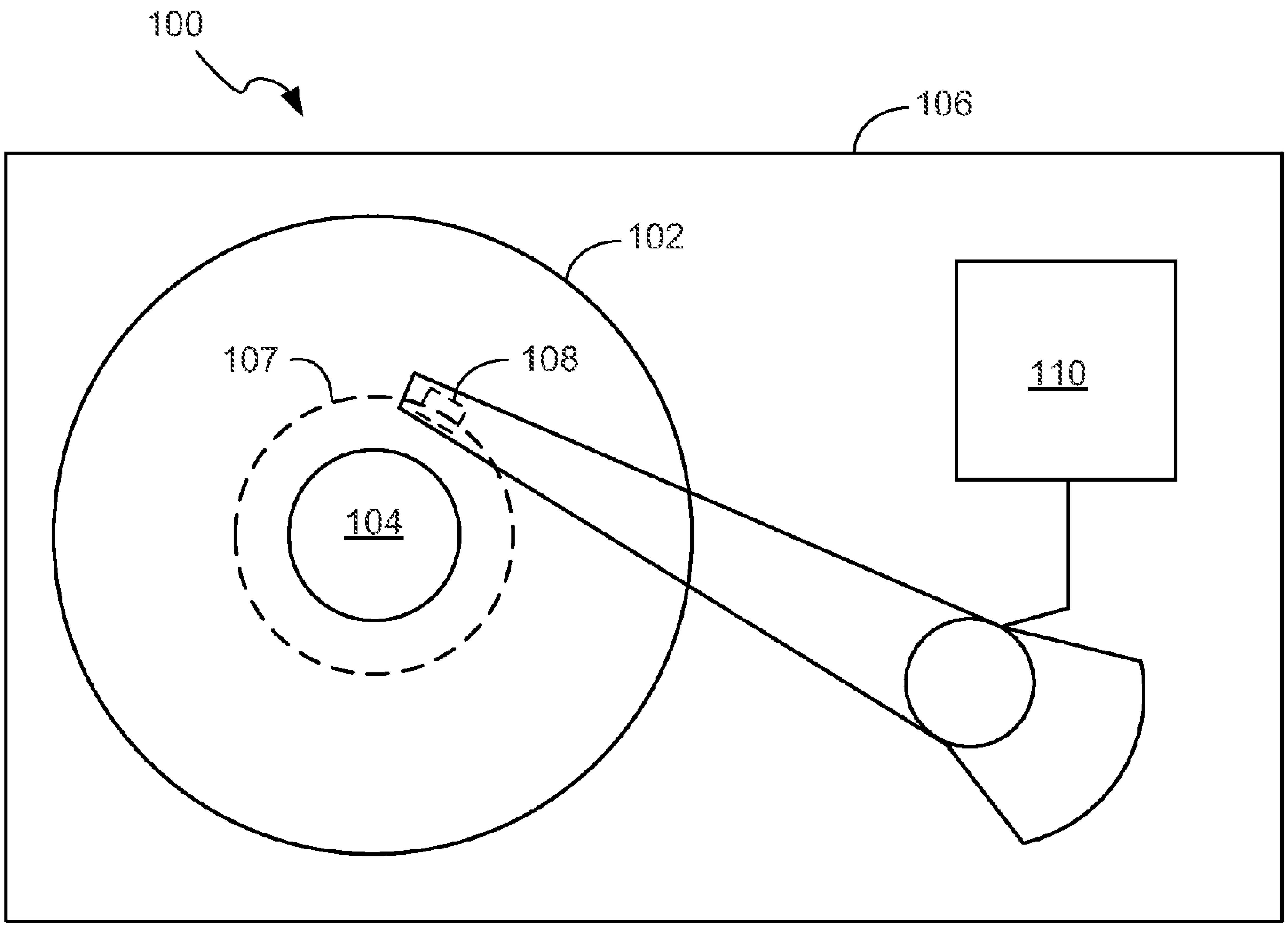


FIG. 1

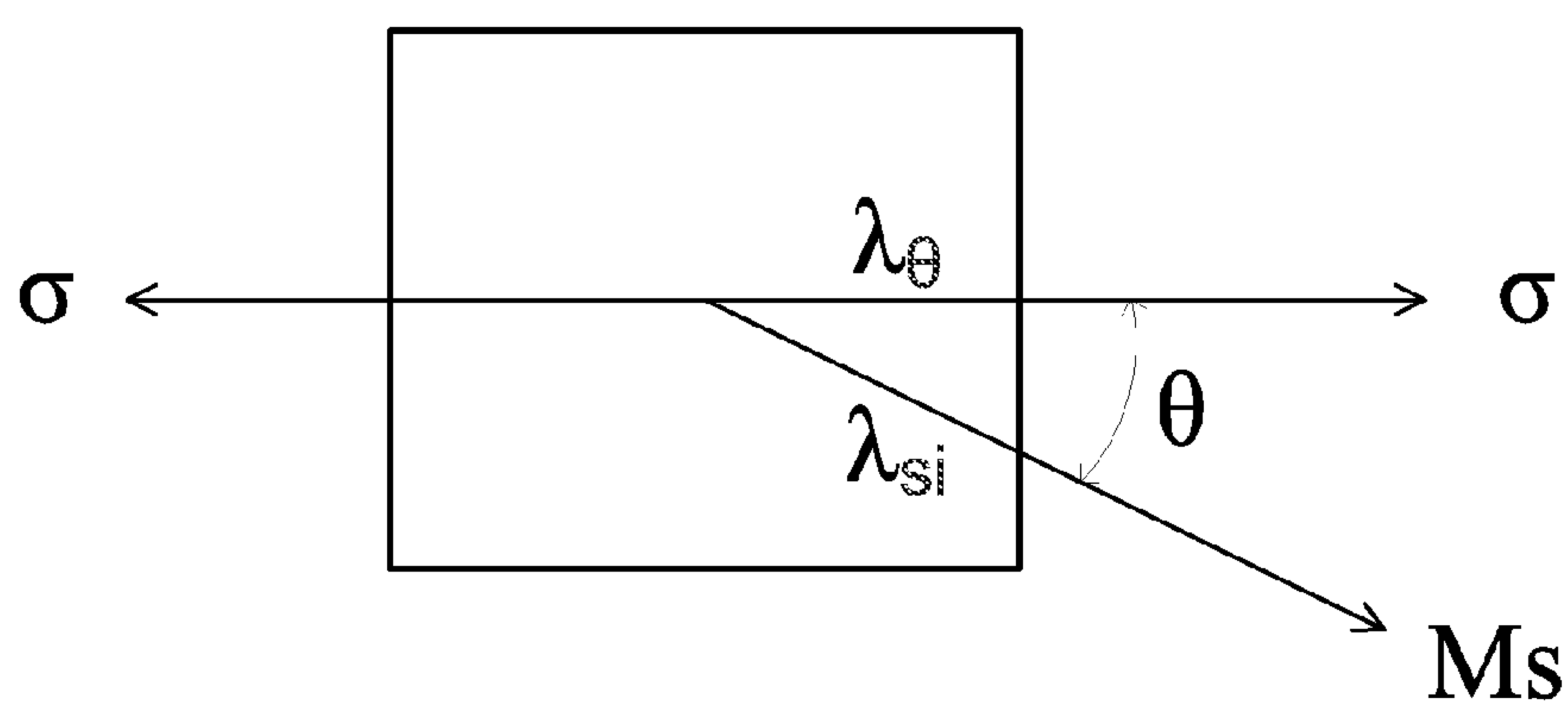


FIG. 2

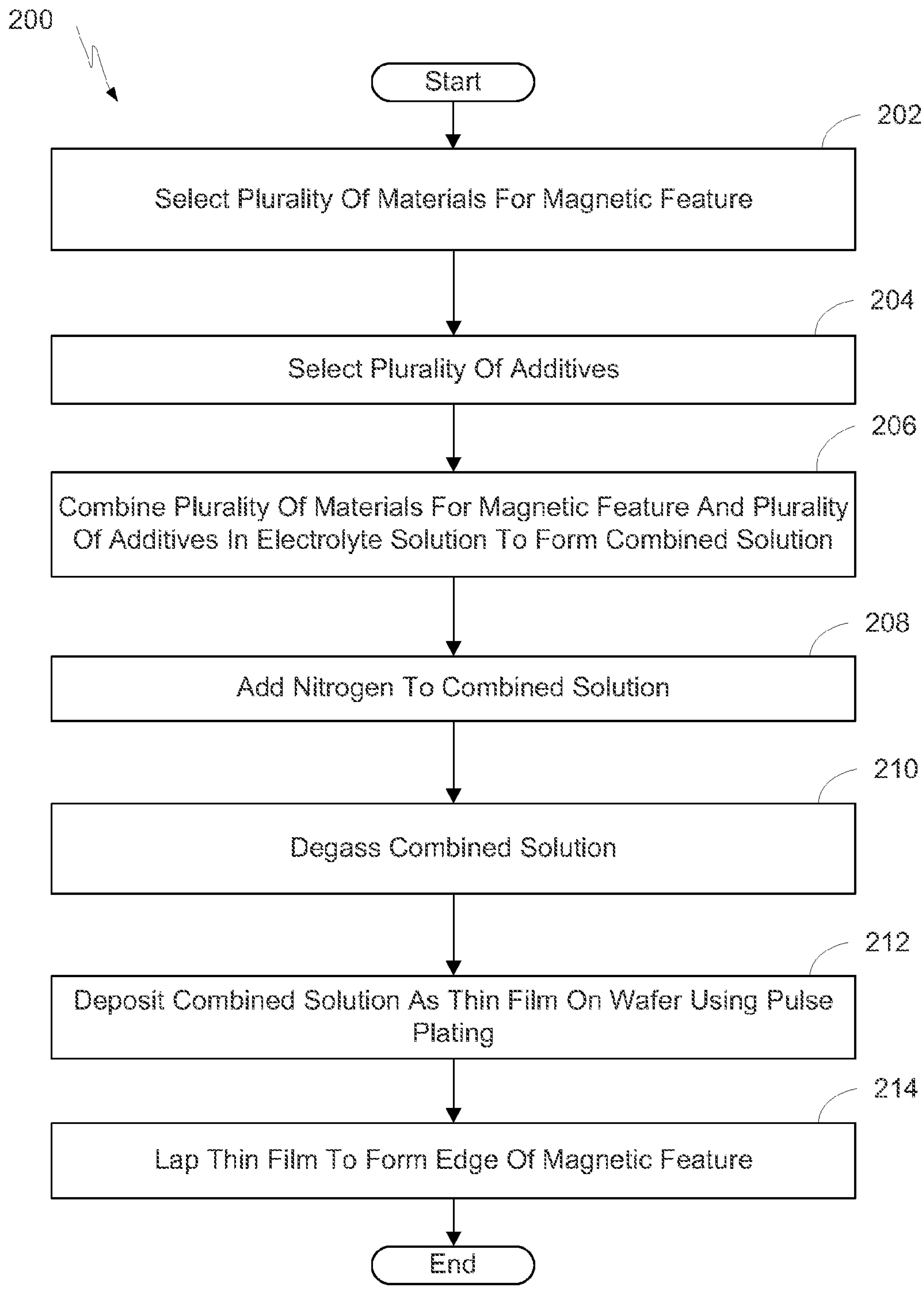

200
Start
202
Select Plurality Of Materials For Magnetic Feature
204
Select Plurality Of Additives
206
Combine Plurality Of Materials For Magnetic Feature And Plurality Of Additives In Electrolyte Solution To Form Combined Solution
208
Add Nitrogen To Combined Solution
210
Degass Combined Solution
212
Deposit Combined Solution As Thin Film On Wafer Using Pulse Plating
214
Lap Thin Film To Form Edge Of Magnetic Feature
End

FIG. 3

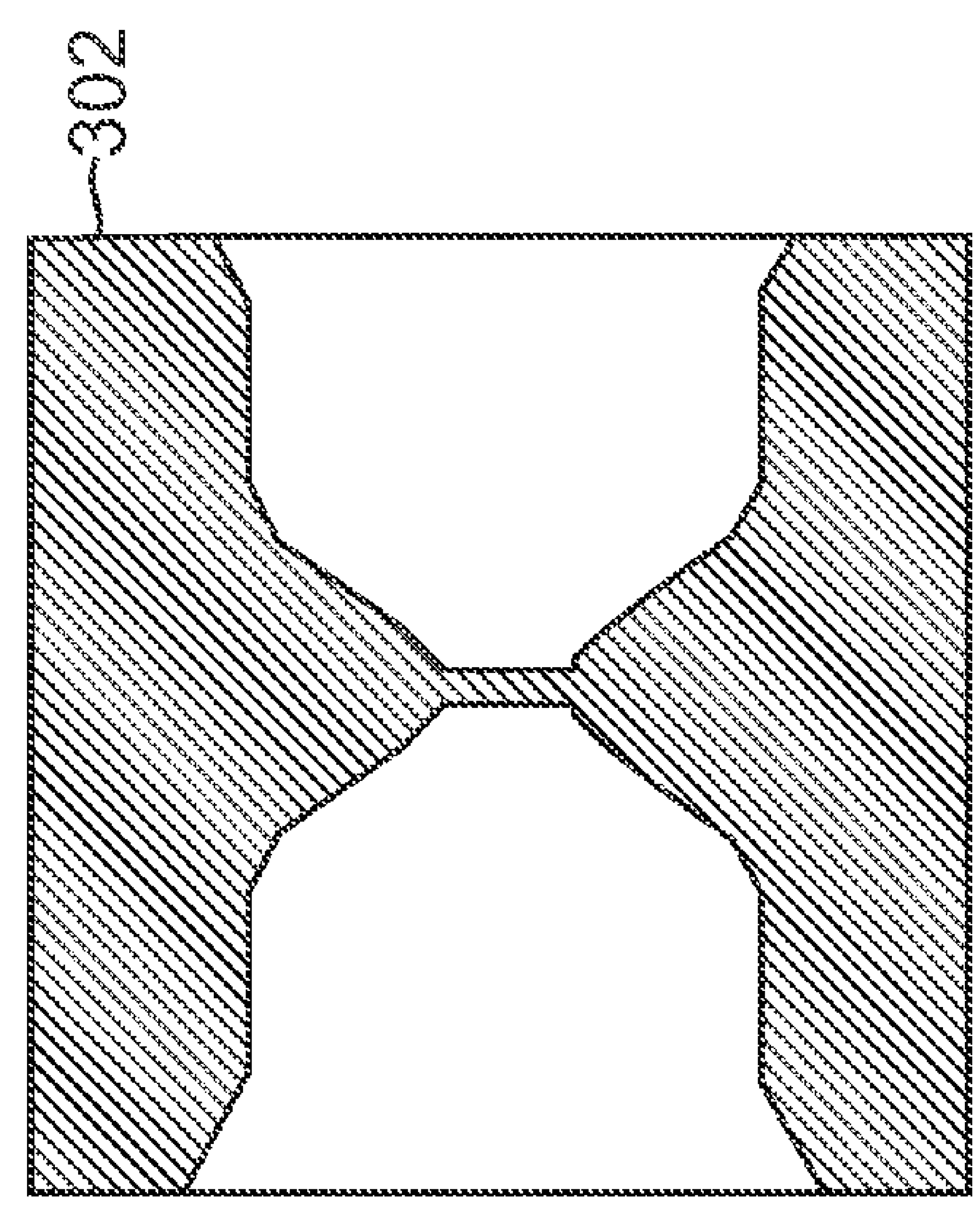


FIG. 4a

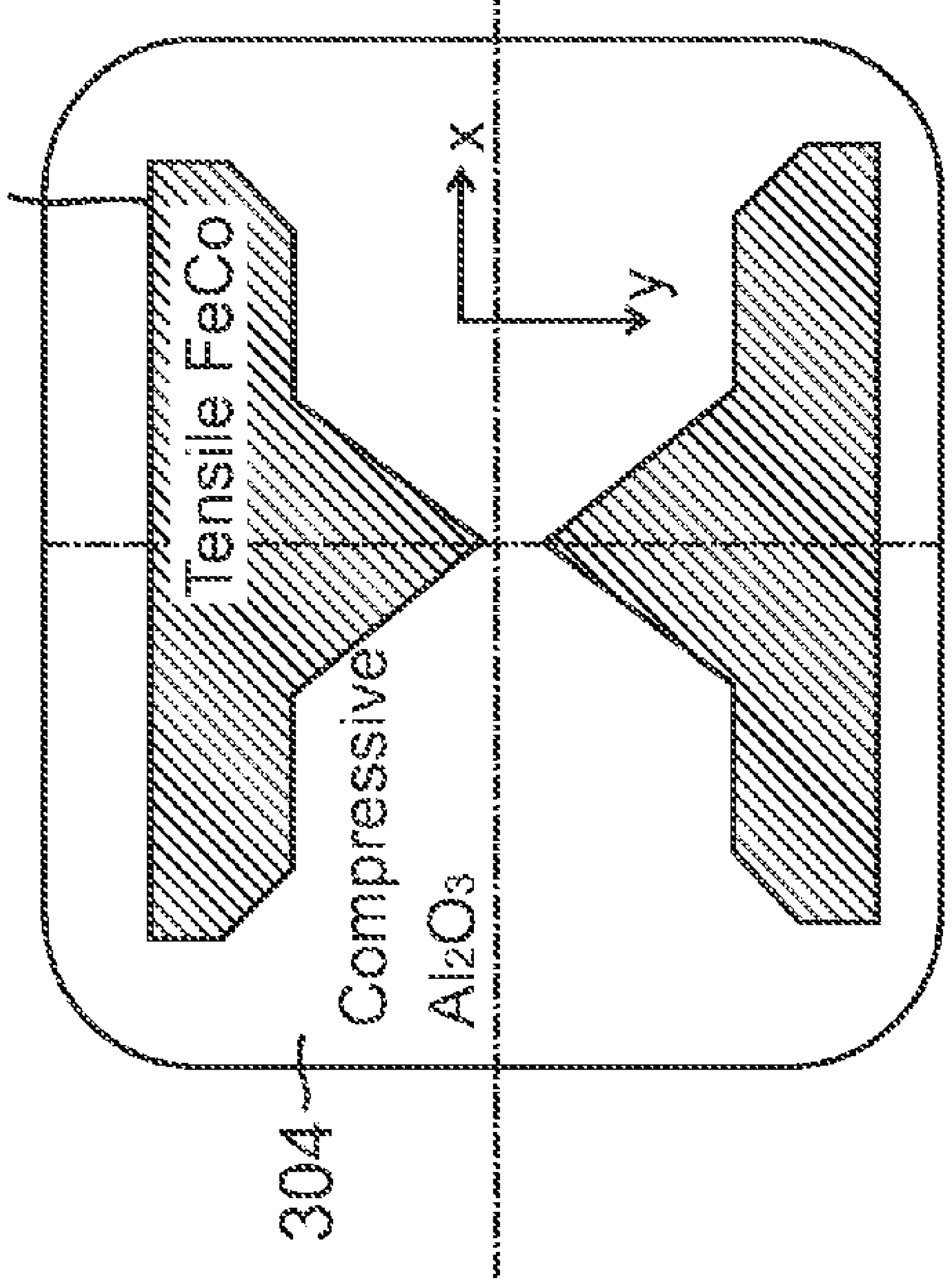


FIG. 4b

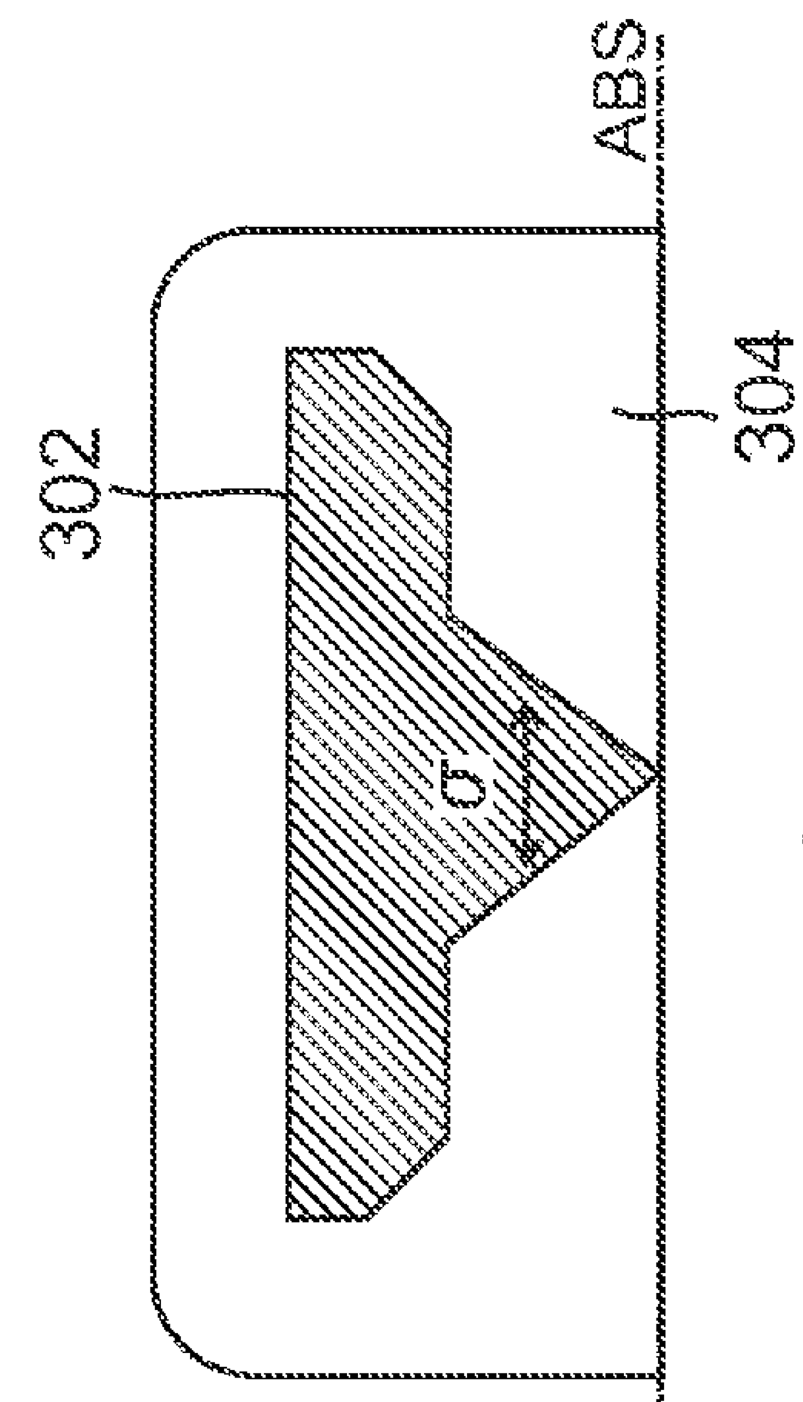


FIG. 4c

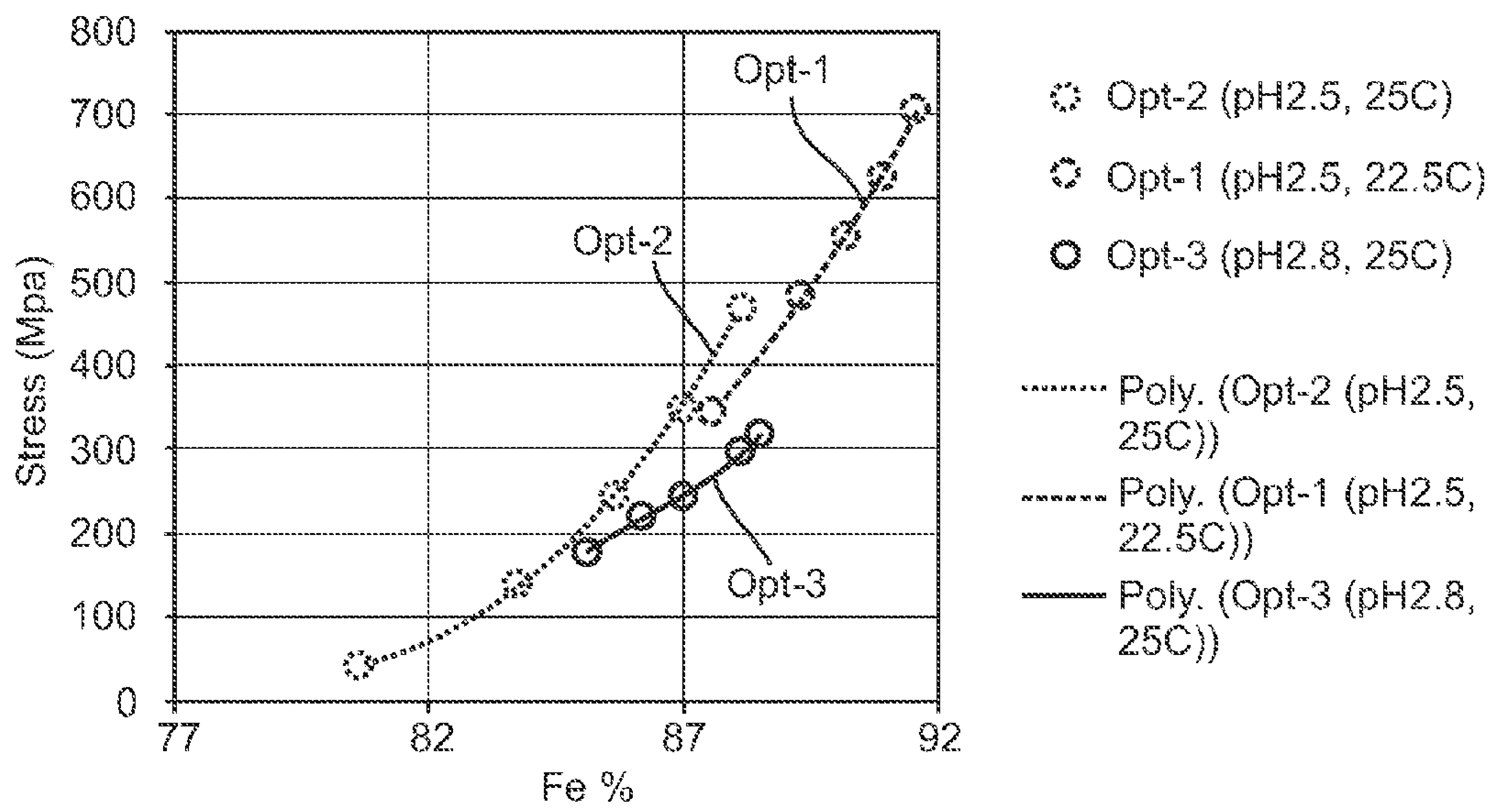

800
700
600
500
400
300
200
100
0
Stress (Mpa)
77
82
87
92
Fe %
Opt-1
Opt-2
Opt-3
Opt-2 (pH2.5, 25C)
Opt-1 (pH2.5, 22.5C)
Opt-3 (pH2.8, 25C)
Poly. (Opt-2 (pH2.5, 25C))
Poly. (Opt-1 (pH2.5, 22.5C))
Poly. (Opt-3 (pH2.8, 25C))

FIG. 5

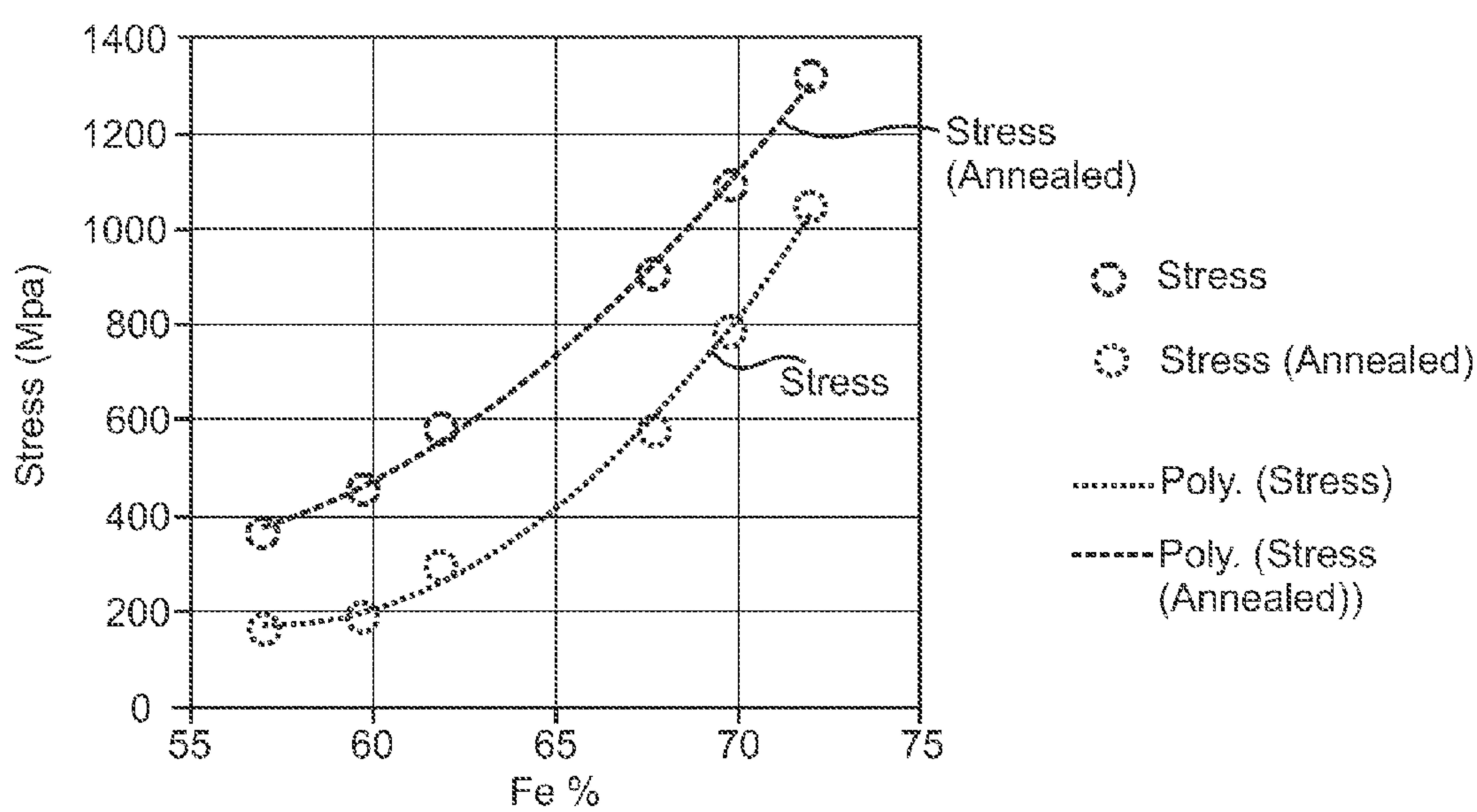
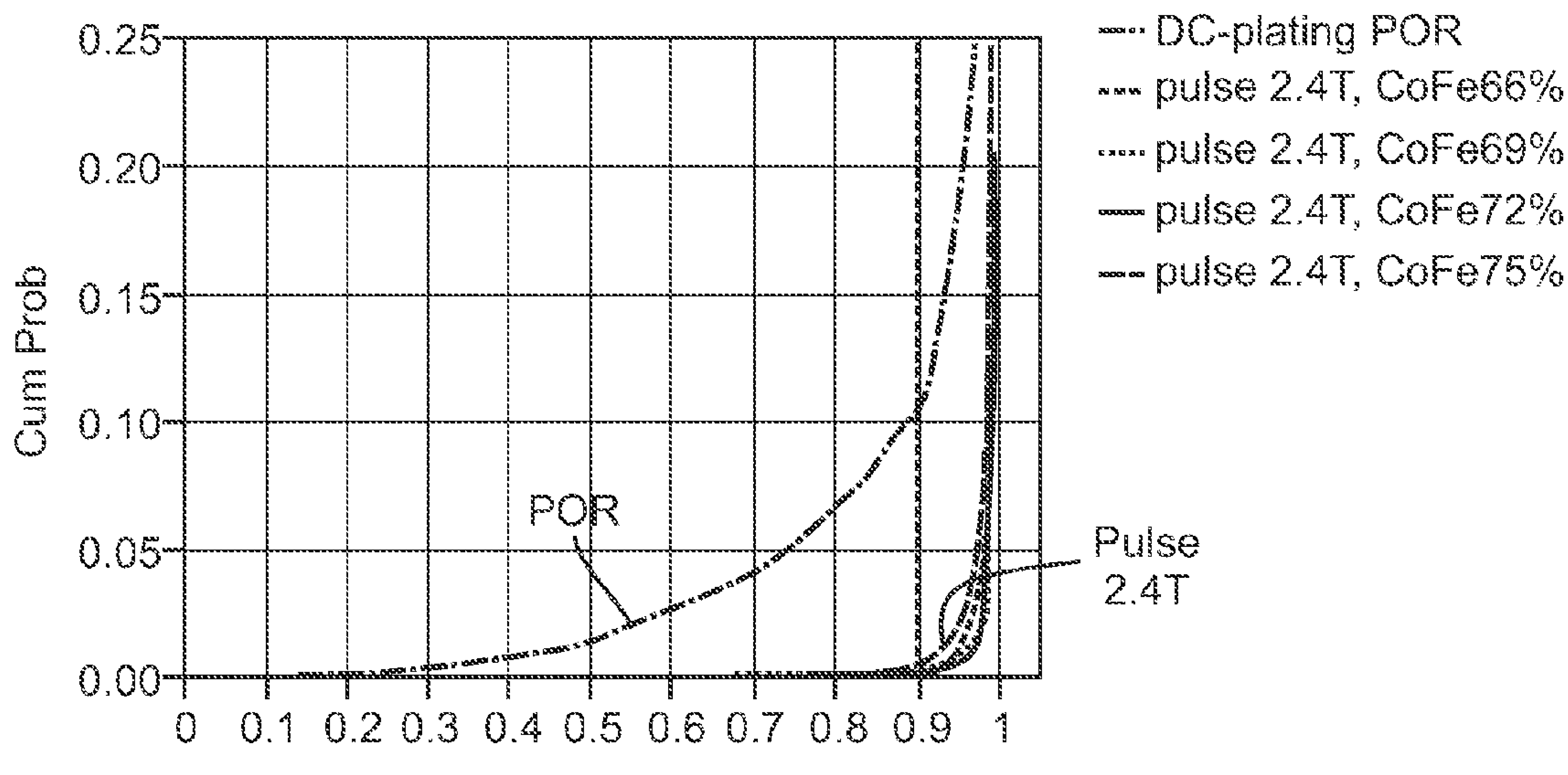
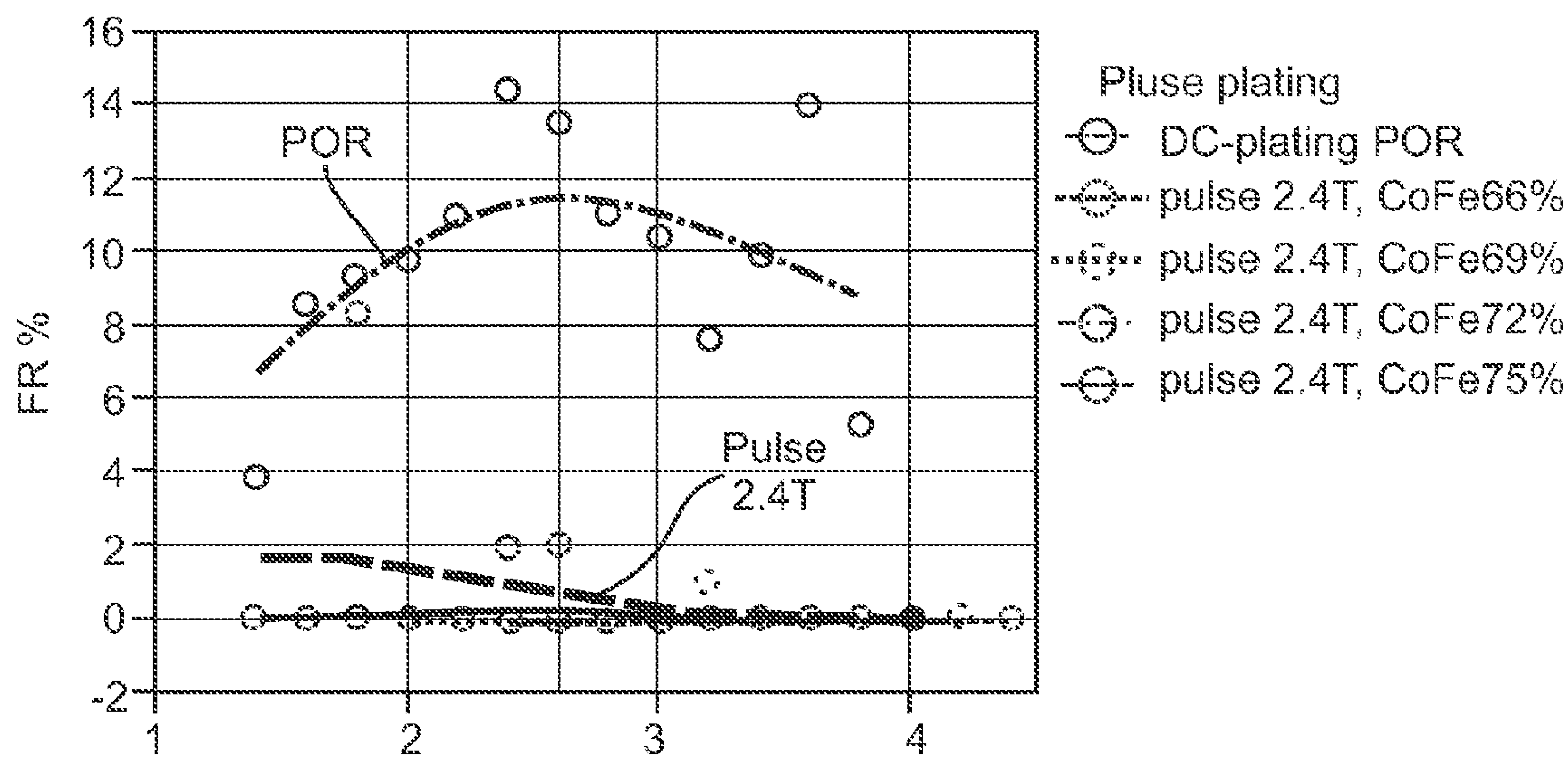

1400
1200
1000
800
600
400
200
0
Stress (Mpa)
55
60
65
70
75
Fe %
Stress (Annealed)
Stress
Stress
Stress (Annealed)
Poly. (Stress)
Poly. (Stress (Annealed))

FIG. 6



DC-plating POR
pulse 2.4T, CoFe66%
pulse 2.4T, CoFe69%
pulse 2.4T, CoFe72%
pulse 2.4T, CoFe75%
Cum Prob
0.25
0.20
0.15
0.10
0.05
0.00
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
POR
Pulse 2.4T

FIG. 7a



Pluse plating
DC-plating POR
pulse 2.4T, CoFe66%
pulse 2.4T, CoFe69%
pulse 2.4T, CoFe72%
pulse 2.4T, CoFe75%
FR %
16
14
12
10
8
6
4
2
0
-2
1 2 3 4
POR
Pulse 2.4T

FIG. 7b

METHODS FOR CONTROLLING STRAY FIELDS OF MAGNETIC FEATURES USING MAGNETO-ELASTIC ANISOTROPY

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority to and the benefit of U.S. Provisional Application No. 61/949,390, filed on Mar. 7, 2014, entitled, "METHODS FOR CONTROLLING STRAY FIELDS OF A MAGNETIC HEAD USING MAGNETO-ELASTIC ANISOTROPY", the entire content of which is incorporated herein by reference.

BACKGROUND

Magnetic storage systems, such as a hard disk drive (HDD), are utilized in a wide variety of devices in both stationary and mobile computing environments. Examples of devices that incorporate magnetic storage systems include desktop computers, portable notebook computers, portable hard disk drives, digital versatile disc (DVD) players, high definition television (HDTV) receivers, vehicle control systems, cellular or mobile telephones, television set top boxes, digital cameras, digital video cameras, video game consoles, and portable media players.

A typical disk drive includes magnetic storage media in the form of one or more flat disks. The disks are generally formed of two main substances, namely, a substrate material that gives it structure and rigidity, and a magnetic media coating that holds the magnetic impulses or moments that represent data. Such disk drives also typically include a read head and a write head (e.g., writer), generally in the form of a magnetic transducer which can sense and/or change the magnetic fields stored on the disks.

Main pole domain lock up, on track erasure, and side track erasure are typical writer reliability issues. All of these issues are related to writer/head stray fields, which can erase the media unintentionally. As such, a method for controlling stray fields of a writer or other magnetic feature is needed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top schematic view of a disk drive including a write head that has been fabricated to minimize stray fields in accordance with one embodiment of the invention.

FIG. **2** is a conceptual schematic diagram of a cube of magnetic materials illustrating some basic physics associated with magneto-elastic energy anisotropy and related writer fabrication characteristics that can be controlled to minimize stray fields in accordance with one embodiment of the invention.

FIG. **3** is a flow chart of a process for controlling stray fields of a magnetic feature that can be used to fabricate a write head in accordance with one embodiment of the invention.

FIGS. **4***a*, **4***b*, **4***c* are schematic cross sectional views of a writer having a writer pole formed of tensile materials disposed within a trench formed of compressive materials in accordance with one embodiment of the invention.

FIG. **5** is a graph of stress versus film Fe concentration for a NiFe film write head subjected to various pH levels and temperatures during write head fabrication in accordance with one embodiment of the invention.

FIG. **6** is a graph of stress versus film Fe concentration for a pulse plated FeCo film write head that was subjected to annealing and pulse plating during write head fabrication in accordance with one embodiment of the invention.

FIG. **7***a* is a graph of the probability of a domain lock up issue for a write head that has been fabricated to minimize stray fields in accordance with one embodiment of the invention.

FIG. **7***b* is a graph of domain lock up (DLU) failure rate for a write head that has been fabricated to minimize stray fields in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

In order to address the stray field problem, one can enhance the magnetic anisotropy to the preferred direction. Most commonly, designers might utilize the magnetic shape anisotropy, and/or crystalline anisotropy to achieve something like this. However, due to the complexity of three dimensional (3-D) structures in current perpendicular magnetic writers, most of the time the shape anisotropy is not in the preferred direction. The 3-D device fabrication also limits the implementation of the crystalline anisotropy.

Referring now to the drawings, embodiments of systems and methods for controlling these stray fields of a magnetic feature are illustrated. The methods can involve selecting a plurality of materials for a magnetic feature, selecting a plurality of additives, combining the plurality of materials for the magnetic feature and the plurality of additives in an electrolyte solution to form a combined solution, adding nitrogen (N) to the combined solution, degassing the combined solution, depositing the combined solution as a thin film on a wafer using pulse plating, and lapping the thin film to form an edge of the magnetic feature. In several embodiments, the magnetic feature is a component of a magnetic transducer such as a writer pole, a reader shield, or a writer shield. The systems can involve a magnetic transducer implemented with one of the methods for controlling stray fields of the magnetic feature (e.g., write head).

FIG. **1** is a top schematic view of a disk drive **100** including a write head (e.g., contained with a slider) **108** that has been fabricated to minimize stray fields in accordance with one embodiment of the invention. Disk drive **100** may include one or more of the disks/media **102** to store data. Disks/media **102** reside on a spindle assembly **104** that is mounted to drive housing **106**. Data may be stored along tracks **107** in the magnetic recording layer of disk **102**. The reading and writing of data is accomplished with the slider/head **108** that can have both read and write elements. The write element (e.g., write head or writer) is used to alter the properties of the magnetic recording layer of disk **102** and thereby write information thereto. In one embodiment, the read element of the head **108** may have tunnel magneto-resistance (TMR) elements.

In operation, a spindle motor (not shown) rotates the spindle assembly **104**, and thereby rotates disk **102** to position head **108** at a particular location along a desired disk track **107**. The position of head **108** relative to disk **102** may be controlled by position control circuitry **110**.

FIG. **2** is a conceptual schematic diagram of a cube of magnetic materials illustrating some basic physics associated with magneto-elastic energy anisotropy and related writer fabrication characteristics that can be controlled to minimize stray fields in accordance with one embodiment of the invention. A tensile stress (σ) is applied to the unit cube, and a magnetization (Ms) of the magnetic materials is initially parallel to the stress. Let Ms then rotate through an angle θ. As it does so, the material will contract along the stress axis when a magneto-striction (λ) is positive. This contraction, in the presence of a tensile stress, means that work is done on the materials. This work is stored as magneto-elastic energy (shifting the system to higher energy state, which may not be preferable) in the materials and is given by the equation:

$$dEms=-\sigma d\lambda$$

for an infinitesimal rotation of Ms.

To maximize the utilization of magneto-elastic anisotropy and thereby minimize the stray field in the magnetic head, aspects of the invention involve a design process to control the materials and structure to meet preselected requirements, such as those illustrated in FIG. **2**. For high density type magnetic writer heads, the structure and the materials can be carefully selected and fabricated (e.g., designed) to ensure that no stray field or minimal stray fields come out from the air bearing surface (ABS). In such case, issues like domain lock up (DLU), side track erasure or on track erasure can be reduced or prevented all together. In one embodiment, these goals can be achieved by utilizing the magneto-elastic anisotropy of the system.

FIG. **3** is a flow chart of a process **200** for controlling stray fields of a magnetic feature that can be used to fabricate a write head in accordance with one embodiment of the invention. In particular embodiments, the process **200** can be used to fabricate the write head of FIG. **1**. In some embodiments, the magnetic feature can be a component of a magnetic transducer such as a writer pole, a reader shield or a writer shield. In block **202**, the process selects a plurality of materials for a magnetic feature. In block **204**, the process selects a plurality of additives. In several embodiments, the process selects the materials (e.g., Fe) such that a product of a magneto-striction of the materials for the magnetic feature and a tensile stress of the materials for the magnetic feature is a positive value. In one such case, the material selection involves selecting a dopant and/or the plurality of additives that such that the product of the magneto-striction and the tensile stress is the positive value. The dopants can include one or more materials such as S, O, H, N, C, and combinations of those materials. For example, the process can add one or more of S at about 5×10^20 atoms per cm3, O at about 5×10^20 atoms per cm3, H at about 5×10^20 atoms per cm3, and/or N at about 5×10^20 atoms per cm3. In one such embodiment, providing higher H and lower S can result in higher stress for the pole materials. In one embodiment, the process can select the materials for the writer pole and one or more organic additives to facilitate design features such as high moment, softness and high stress.

In one embodiment, the plurality of additives includes hydroxylmethyl-P-tolysulfone (HPT) in a concentration between about 0 to about 10 parts per million. In other embodiments, other suitable additives can be used. In block **206**, the process combines the plurality of materials for the magnetic feature and the plurality of additives in an electrolyte solution to form a combined solution. In block **208**, the process adds nitrogen (N) to the combined solution. In one embodiment, adding the nitrogen can effectively remove oxygen from the combined solution. In several embodiments, the process adds the write pole materials and the organic additives to the electrolyte solution with about 0 to about 0.05 ppm of dissolved oxygen.

In block **210**, the process degasses the combined solution. In one embodiment, the degassing can remove oxygen and N from the combined solution. In one embodiment, the degassing involves applying a vacuum pressure to a membrane in contact with the combined solution. In such case, the membrane can be configured to allow gas to pass but not liquid. More specifically, the membrane can be configured to allow gas to escape the electrolyte solution but prevent passage of any liquid, thereby helping to eliminate any gas, such as oxygen, from the electrolyte solution. In one embodiment, the electrolyte solution has about 0 to about 0.05 ppm of Fe3+ (e.g., minimal Fe3+ since the oxygen has been minimized or eliminated).

In block **212**, the process deposits the combined solution as a thin film on a wafer using pulse plating. Pulse plating of these types of pole materials (e.g., to minimize surface roughness) is described in co-pending U.S. patent application Ser. No. 13/423,009, filed on Mar. 16, 2012, and entitled, "METHOD OF ELECTROPLATING IRON-COBALT ALLOY FILMS USING PULSED ELECTROPLATING METHODS", the entire content of which is incorporated herein by reference.

In block **214**, the process laps the thin film to form an edge of the magnetic feature. In several embodiments, the lapping can optimize the directional stress as described above.

In several embodiments, the magnetic feature is a writer pole. In one such case, the plurality of materials for the magnetic feature can include CoFe having an Fe content between about 50 and about 75 percent. In another such case, the plurality of materials for the magnetic feature include CoFe with a preselected Fe content, where the plurality of additives are selected to achieve the preselected Fe content.

In several embodiments, the magnetic feature includes Fe and the process further provides a sacrificial anode immersed in the combined solution to reverse oxidation of the Fe. In one such case, the magnetic feature includes Fe2+ and the process further provides the sacrificial anode immersed in the combined solution to reverse oxidation of the Fe3+.

In several embodiments, the majority of the writer magnetic materials are electroplated (by volume) alloys, and the properties of electroplated magnetic alloys can be easily tuned by altering the plating process. In several such embodiments, aspects of this invention can utilize the high tensile stress of these magnetic alloys.

In one embodiment, the process of FIG. **3** can perform the sequence of actions in a different order. In another embodiment, the process can skip one or more of the actions. In other embodiments, one or more of the actions are performed simultaneously. In some embodiments, additional actions can be performed.

FIGS. **4**_a_, **4**_b_, **4**_c_ are schematic cross sectional views of a writer having a writer pole **302** formed of tensile materials (e.g., FeCo) disposed within a trench **304** formed of compressive materials (e.g., Al2O3) in accordance with one embodiment of the invention.

In one embodiment, the fabrication process of FIG. **3** can involve a different combination of stages. For example, in a first stage of a second exemplary process, the process can involve biasing a sign of the product of the material characteristics (product of magneto-striction and tensile stress or $\lambda\sigma$) to configure the system magneto-elastic anisotropy to minimize or eliminate any stray fields. For example, with a positive product of $\lambda\sigma$, σ should be parallel to the Ms direction to have the preferred magneto-elastic state (e.g., see FIG. **2** where the direction of Ms is close to being parallel to the direction of σ). However, for a negative product of $\lambda\sigma$, σ would be at about 90 degrees relative to the Ms direction, which would not be preferred.

In one example embodiment for a perpendicular magnetic main writer pole where FeCo materials are used as high moment materials, the remanent Ms direction needs to be contained within a plane of the ABS surface, which can be defined as being along the x direction as depicted in FIG. **4***b*. In such case, since the plated FeCo materials for this example have a positive magneto-striction (λ), the σ (positive tensile stress) anisotropy can be developed to be as high as possible.

In a second stage of the second exemplary process, the writer structure can be formed with the stress anisotropy in the preferred direction. To introduce the stress anisotropy in the writer, the three dimensional structure can be formed by first constructing the trench, then backfilling the magnetic materials, and finally cutting (e.g., lapping or removing) one side of trench structure to relax the stress of backfilled materials inside the trench in that direction.

Still using the FeCo writer as an example, as described earlier, it may be preferable to have higher tensile stress in the writer application. By choosing high Young's Modulus type trench materials (compressive Al2O3 for example) with the good adhesion between the backfill materials and trench side wall, the backfilled FeCo tensile stress can be preserved. In fact, the FeCo tensile stress can be even higher after thermal annealing. At this stage of the second exemplary process, the system may have high isotropic stress, which may not benefit the design goal until after one side of the trench materials has been removed. After lapping through the trench along the ABS surface (see FIG. **4***c* for example), the backfilled FeCo high tensile stress gets relaxed in the direction normal to the ABS, which can provide the high stress anisotropy for the FeCo materials remaining in the trench. More precisely, FeCo materials will have strong tensile stress along the x direction in the trench, as shown in FIGS. **4***a*, **4***b*, and **4***c*.

In some embodiments, the thin film FeCo has improved corrosion properties (e.g., Ecorr is about −400 mV versus Ag/AgCl reference electrode). In one embodiment, the FeCo film resistivity is less than about 27 micro ohm cm at a film Fe concentration percentage of about 70%. In one embodiment, the HPT byproduct concentration is about 0 to about 10 ppm (0.01 g/l), and includes byproducts such as p-Toluenesulfinte and p-Toluenesulfonate.

In using the positive λ and positive σ for the FeCo pole materials, the constructed high anisotropy tensile stress (magneto-elastic energy anisotropy) can promote the Ms to stay in the x direction (e.g., the preferred low energy state that is roughly parallel to the ABS).

In a third stage of the second exemplary process, the pole material's increased tensile stress can result in stray fields with a preferential orientation (e.g., cross track but parallel to ABS or in the x direction in FIG. **4***b*). In one aspect for pole damascene, the higher the tensile stress of the FeCo pole materials, the better the writer pole (e.g., writer) will reduce the stray fields along the y direction, thereby reducing or eliminating the potential domain lock up at the pole tip.

In a fourth stage of the second exemplary process, the use of compressive pole materials may be considered. For highly compressive pole materials, the magneto-striction (λ) may need to be negative to have the same effect.

In a fifth stage of the second exemplary process, it can be considered whether a particular application needs to have stray fields come out of the trench lapping surface. If so, the negative λσ materials can be picked by increasing the stress number.

In a sixth stage of the second exemplary process, aspects of the invention can be considered for applications other than a writer. For example, the way to construct the three dimensional feature, the method to grow the property matched material, and the design to utilize the produced magneto-elastic energy term can be generalized for many applications. For magnetic recording, one or more of the magnetic shield layers in the head can benefit from the magnetic writer fabrication processes in a similar way. That is, they may benefit by controlling the stray fields to prevent the unintended erasure.

FIG. **5** is a graph of stress versus film Fe concentration for a NiFe film write head subjected to various pH levels and temperatures during write head fabrication in accordance with one embodiment of the invention. The first option ("Opt-1") illustrates the NiFe film write head subjected to a pH level of 2.5 and a temperature of 22.5 degrees Celsius (C). The second option ("Opt-2") illustrates the NiFe film write head subjected to a pH level of 2.5 and a temperature of 25 degrees C. The third option ("Opt-3") illustrates the NiFe film write head subjected to a pH level of 2.8 and a temperature of 25 degrees C. As can be seen in FIG. **5**, fitted polynomial lines have been superimposed on the data points for each of the three options.

FIG. **6** is a graph of stress versus film Fe concentration for a pulse plated FeCo film write head that was subjected to annealing and pulse plating during write head fabrication in accordance with one embodiment of the invention. One set of data shows the stress, in megapascal, with annealing and the other set of data shows the stress without annealing.

Thus, the stress versus film Fe concentration percentage for electroplated NiFe and FeCo are plotted in FIGS. **5** and **6** individually. Both charts indicate that the film stress is function of the film Fe concentration percentage, and that after the write head is thermally annealed, the tensile stress of those materials is further increased.

As an experiment, DC plated FeCo film (which can include properties such as low stress film and low magneto-elastic anisotropy) and pulse plated FeCo film (which can include properties such as high stress and high magneto-elastic anisotropy) have been deposited into a device damascene pole trench (e.g., made of alumina), for given positive magneto-striction FeCo materials. The high tensile stress pulse plated FeCo (as compared to the DC plated FeCo) is expected to have better aligned magnetization along the x direction (within the ABS surface). Backend device domain lock up (DLU) test results have confirmed this, as shown in FIGS. **7***a* and **7***b*.

FIG. **7***a* is a graph of the probability of a domain lock up issue for a write head that has been fabricated to minimize stray fields (e.g., high stress CoFe with varying material concentrations) in accordance with one embodiment of the invention. More specifically, the pulse plating is consistently 2.4 Tesla, while the CoFe has varying Fe percentages of 66, 69, 72, and 75. A reference write head performance is shown for a standard write head with DC plating (see "DC-plating POR" and "POR" curve).

FIG. **7***b* is a graph of domain lock up (DLU) failure rate (FR in percent) for a write head that has been fabricated to minimize stray fields (e.g., high stress CoFe with varying material concentrations) in accordance with one embodiment of the invention. Similar to the graph of FIG. **7***a*, the graph of FIG. **7***b* includes data from write heads involving pulse plating consistently at 2.4 Tesla, while the CoFe has varying Fe percentages of 66, 69, 72, and 75. A reference write head performance is shown for a standard write head with DC plating (see "DC-plating POR" and "POR" curve).

In several embodiments, pulse plated high magneto-elastic energy (high stress) materials has significantly improved domain lock up (DLU) performance.

Most recently, these high magneto-elastic anisotropy (high stress) pulse plated FeCo pole materials have been qualified as being suitable for certain writer pole applications. Magneto-striction is an intrinsic material property, and for most high moment electroplated soft magnetic alloys, it has a positive value. Alloy stress is function of film Fe concentration percentage. High Fe content in the film is one of the signatures of a high stress film which can be utilized to optimize the magneto-elastic energy for head overall stability improvement.

The terms "above," "below," and "between" as used herein refer to a relative position of one layer with respect to other layers. As such, one layer deposited or disposed above or below another layer may be directly in contact with the other layer or may have one or more intervening layers. Moreover, one layer deposited or disposed between layers may be directly in contact with the layers or may have one or more intervening layers.

In several embodiments, the deposition of materials described herein can be performed using a variety of deposition sub-processes, including, but not limited to physical vapor deposition (PVD), sputter deposition and ion beam deposition, and chemical vapor deposition (CVD) including plasma enhanced chemical vapor deposition (PECVD), low pressure chemical vapor deposition (LPCVD) and atomic layer chemical vapor deposition (ALCVD). In other embodiments, other suitable deposition techniques known in the art may also be used.

While the above description contains many specific embodiments of the invention, these should not be construed as limitations on the scope of the invention, but rather as examples of specific embodiments thereof. Accordingly, the scope of the invention should be determined not by the embodiments illustrated, but by the appended claims and their equivalents.

The various features and processes described above may be used independently of one another, or may be combined in various ways. All possible combinations and sub-combinations are intended to fall within the scope of this disclosure. In addition, certain method, event, state or process blocks may be omitted in some implementations. The methods and processes described herein are also not limited to any particular sequence, and the blocks or states relating thereto can be performed in other sequences that are appropriate. For example, described tasks or events may be performed in an order other than that specifically disclosed, or multiple may be combined in a single block or state. The example tasks or events may be performed in serial, in parallel, or in some other suitable manner. Tasks or events may be added to or removed from the disclosed example embodiments. The example systems and components described herein may be configured differently than described. For example, elements may be added to, removed from, or rearranged compared to the disclosed example embodiments.

What is claimed is:

1. A method for controlling stray fields of a magnetic feature, the method comprising:

determining a product of a magneto-striction and a tensile stress for candidate materials for a magnetic feature;

selecting a plurality of materials for the magnetic feature from the candidate materials such that the product of the magneto-striction and the tensile stress of the magnetic feature is a positive value;

selecting a plurality of additives;

combining the plurality of materials for the magnetic feature and the plurality of additives in an electrolyte solution to form a combined solution;

adding N to the combined solution;

degassing the combined solution;

depositing a thin film on a wafer from the combined solution using pulse plating to form the magnetic feature having the positive value; and

lapping the thin film to form an edge of the magnetic feature.

2. The method of claim **1**, wherein the magnetic feature is a component of a magnetic transducer selected from the group consisting of a writer pole, a reader shield, and a writer shield.

3. The method of claim **1**, wherein the selecting the plurality of materials for the magnetic feature from the candidate materials such that the product of the magneto-striction and the tensile stress of the magnetic feature is the positive value further comprises selecting a dopant and/or the plurality of additives such that the product of the magneto-striction and the tensile stress is the positive value.

4. The method of claim **3**, wherein the dopant is a material selected from the group consisting of S, O, H, N, C, and combinations thereof.

5. The method of claim **1**, wherein the plurality of additives comprise hydroxylmethyl-P-tolysulfone (HPT) in a concentration between about 0 to about 10 parts per million.

6. The method of claim **1**:

wherein the magnetic feature comprises a writer pole; and

wherein the plurality of materials for the magnetic feature comprise CoFe having an Fe content between about 50 and about 75 percent.

7. The method of claim **1**:

wherein the magnetic feature comprises a writer pole;

wherein the plurality of materials for the magnetic feature comprise CoFe with a preselected Fe content; and

wherein the selecting the plurality of additives comprises selecting the plurality of additives to achieve the preselected Fe content.

8. The method of claim **1**:

wherein the adding the N to the combined solution comprises adding the N to the combined solution to remove oxygen from the combined solution; and

wherein the degassing the combined solution comprises degassing the combined solution to remove oxygen and N from the combined solution.

9. The method of claim **1**, wherein the degassing the combined solution comprises applying a vacuum pressure to a membrane in contact with the combined solution.

10. The method of claim **1**:

wherein the magnetic feature comprises Fe; and

the method further comprising providing a sacrificial anode immersed in the combined solution to reverse oxidation of Fe^{3+} present in the combined solution.

11. The method of claim **10**:

wherein the plurality of materials comprise Fe^{2+}; and

wherein the sacrificial anode comprises an active metal and is immersed in the combined solution to reverse oxidation of the Fe^{3+}.

12. The method of claim **1**, wherein the magnetic feature comprises a writer pole.

13. The method of claim **12**:

wherein the selecting the plurality of materials for the magnetic feature from the candidate materials such that the product of the magneto-striction and the tensile stress of the magnetic feature is the positive value further comprises selecting a dopant and/or the plurality of additives such that the product of the magneto-striction and the tensile stress is the positive value; and

wherein the dopant is a material selected from the group consisting of S, O, H, N, C, and combinations thereof.

14. The method of claim **13**, wherein the plurality of additives comprise hydroxylmethyl-P-tolysulfone (HPT) in a concentration between about 0 to about 10 parts per million.

15. The method of claim **14**:

wherein the plurality of materials for the magnetic feature comprise CoFe having an Fe content between about 50 and about 75 percent.

16. The method of claim **15**, wherein the degassing the combined solution comprises applying a vacuum pressure to a membrane in contact with the combined solution.

17. The method of claim **16**:

the method further comprising providing a sacrificial anode immersed in the combined solution to reverse oxidation of Fe^{3+} present in the combined solution.

18. The method of claim **17**:

wherein the plurality of materials comprise Fe^{2+}; and

wherein the sacrificial anode comprises an active metal and is immersed in the combined solution to reverse oxidation of the Fe^{3+}.

19. The method of claim **1**:

wherein the selecting the plurality of materials for the magnetic feature from the candidate materials such that the product of the magneto-striction and the tensile stress of the magnetic feature is the positive value further comprises selecting a dopant and/or the plurality of additives such that the product of the magneto-striction and the tensile stress is the positive value; and

wherein the dopant comprises S, O, H, and N.

20. The method of claim **1**:

wherein the selecting, if the product is the positive value, the plurality of materials for the magnetic feature from the candidate materials further comprises selecting a dopant and/or the plurality of additives such that the product of the magneto-striction and the tensile stress is the positive value; and

wherein the dopant comprises S and H, wherein a concentration of H is greater than a concentration of S.

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